Competitive Market Forecasting of the Merits of Fossil Electric Generation Projects

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Abstract

This paper summarizes an approach being developed by the National Energy Technology Laboratory (NETL) for evaluating the merits of power projects in the various regions of the U.S. These procedures use a number of different computer evaluation modules that collectively have been named "GEMSET," an acronym for "government energy market segment evaluation tool."

Significant changes in the way electricity is sold are occurring in the U.S. These changes mean that there is increased burden on planners to assess the merits of fossil power generation units. Both government and industry planners need to establish the prospects for competitive electric sales under the emerging market for power sales. The paper discusses how GEMSET addresses a range of likelihoods affecting the potential financial return to the owner of an electric generation unit. The paper shows how the modeling system describes factors affecting the existing fleet of units, the proposed technology being evaluated as a potential new unit, and other technologies competing to fill a new load demand need in the various regions of the United States. The GEMSET portfolio of tools allows the investigation of different environmental, demand, and fuel price scenarios that might exist in the various regions. This paper describes how the GEMSET modeling system gives reasoned estimates of plant economics based on projections of where these regional markets might be in the future up to year 2020, under a range of scenarios of possible circumstances. It also shows how these forecasts are made.

Background

Coal-fired generation produces almost 55 percent of America's electricity, yet much of that generating capacity is over 40 years old. Most new electric generation projects have been either natural gas-fueled gas turbines or combined cycles. The recent preference for these natural gas projects has largely been driven by low gas prices that existed in the past, and the acceptable environmental performance of these units. These natural gas units have also been selected due to their lower risk and smaller size increments as the U.S. power market adjusted to new competitive market approaches in some regions.

Still, some significant changes have occurred that might affect future plant decisions, and the choice between gas- or coal-fueled generation. Difficulties in California's competitive market caused some states to pause in their plans to move to a competitive market structure, while other regions, such as PJM, apparently are coping well with competition. The direction of future

environmental regulation leads to uncertainties, and in the past year, natural gas prices have both risen and fallen. Further, new generations of coal and natural gas technologies are or will soon be available to begin commercial service demonstrations. Each of these changes can have a profound effect on the type of power generating unit that has the best prospects of profitable return to its investors.

All this means that there is a significant burden on planners to assess the merits of fossil power generation units to establish their prospects for competitive electric sales. Planners need to explore different likely future power industry circumstances, and make decisions on investments in new power plant units that remain economically robust over a reasoned range of possible future circumstance. This paper summarizes an approach being used and developed by NETL for evaluating the merits of coal- and gas-fired power projects in those areas of the country that have gone to a competitive market.

The GEMSET product promotes the reasoned evaluation of the economic and environmental prospects of fossil electric power generation technologies in the both the competitive and regulated market regions of the United States. The evaluations and tools in the GEMSET product allow assessment of the existing plant investment and financial return conditions throughout the U.S. These tools and assessments also allow the investigation of different future environmental, demand, and fuel price scenarios that might exist in the various regions. The computer modeling system gives reasoned projections of where these circumstances might, under a range of varying circumstances, exist in the future up to the year 2020. GEMSET evaluations include the following evaluation support elements:

- A view of historical electric demand in each region
- Projections of demand under differing circumstances in these regions in the future
- A view of historical and projected fuel prices to generating company owners in each region.
- An estimate of the unit use patterns and capacity factor that might be expected under this forecast of future circumstances.
- An assessment of the expected revenue prospects of a generating company owner in the various regions of the U.S. under these circumstances.
- Assessments of how the revenue prospects might change under differing fuel price scenarios.
- Assessments of how the revenue prospects change under different environmental regulation scenarios.

This paper describes the various elements of the GEMSET market modeling approach already developed. It shows examples of results from using these elements to evaluate power generating unit addition projects in the PJM and NYISO regions. Finally, the paper gives a summary of where the modeling effort will proceed.

The GEMSET Modeling System

Generating company owners take significant risk when they invest their money in new electric generation equipment. Several important factors affect the ability of the owner to make a profit on a new electric generating unit. These include the following:

- How well the owner anticipates how much demand there will be for the sale of electricity from the new generation unit,
- How well the owner is able to estimate the price received for that electricity, and
- How well the owner can anticipate how much it will cost to operate the unit.

Of necessity, addressing these also requires close attention to factors that include at least the following:

- Understanding the region's operating rules and regulations.
- Understanding the way units are planned and permitted to add new generation in a region.
- Anticipating retirements of existing units.
- Understanding the present and historical fuel costs, and anticipating how these might change in the future.
- Understanding present environmental regulation, and anticipating how these regulations might change and affect the cost of operating the owner's unit and competing units in the future.
- Understanding how to operate in a market – significantly different if that market is regulated or competitive, anticipating how other owners will operate their units, estimating the costs to which these competing units might be subject, and forecasting the revenue expected from their operations under these circumstances.

In order to better plan, research, and develop practical solutions for America's power future, NETL shares many of the same project evaluation needs as power plant owners evaluating how new electric generating technologies might be received, and how their prospects might change under different future economic and regulatory circumstances.

NETL embarked on a program to develop power market information. A series of program elements are under development to support NETL's internal technology economic evaluation and assessment needs. This collection of GEMSET model elements allows the NETL to select from well researched historical regional load demand / price scenarios, and capacity factor information in a region, or on reasoned extrapolations to possible future price

circumstances for a range of reasonable different circumstances. The collection of models assesses the capacity factor expected in that region under the user's input circumstances for his or her study unit, and assesses the financial return expected under that scenario of circumstances.

Significance

The money needed to buy a fossil-fired power plant for electric power generation is substantial. An owner might risk $400 million to build a 400 megawatt coal plant to meet electric needs during baseload demand periods, or $195 million to build a 400 megawatt combined cycle. When making a decision about investing this amount of money, good judgment about cost and return is important.

Because so much money is at stake, higher-than-expected fuel price can result in the owner losing money until fuel price drops or electric sale price rises; if the problem with price persists, the project could even fail financially. Similarly, if apprehension about profit from such a large investment causes the potential owner to cancel or abandon development of a new plant, needed units might not be built in time to meet demand growth, affecting grid reliability and peak demand prices during an energy shortfall. With good information and appropriate planning, potentially disastrous financial investments are avoided, and sufficient signals exist to build an adequate supply and backup of new generation for reliable electricity at acceptable price to the consumers. Good planning information improves the likelihood that adequate new generation to meet expected demand in a region is provided, and that a solid financial return is made for profitable operations for the investors in that new generation and stability of reliable power. Appropriate construction avoids both electric power shortages and skyrocketing electric price to consumers during peak demand periods that otherwise occurs when there are inadequate resources.

If NETL is to assist industry in providing the new electric generation technology to support America's energy future, it is important that these emerging technologies for generation provide superior choices to those already in the generation mix. The new technology must prove as reliable, as cost effective, or it will not penetrate the power generation market. NETL's assessment needs thus parallel the needs of industry, and must realistically assess the needs and financial returns of plant investors.

Evaluating Power Plant Economics

The GEMSET methods evaluate electricity price, revenue, and unit capacity factors to approximate how generating company owners choose to bid their units into competitive and regulated electric markets. The user can review the capacity factor that the GEMSET model predicts when that unit operates under any of the range of the pre-loaded regional operational scenarios. The user can specify how a unit might be expected to perform, and what its costs will be, or can select from a library of power generation technologies. The model provides estimates of what results might typically be obtained for coal units of different output ratings under the

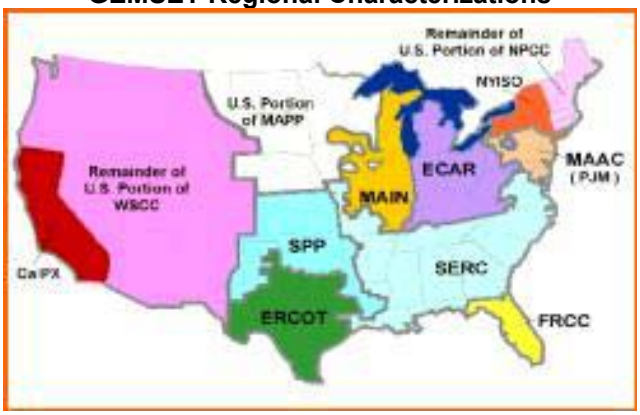
same circumstances, used as benchmarks to compare the merits of the study unit to those of the most likely technologies that would also be considered by the owner before the owner would make an investment decision. The model also provides natural gas-fueled competition benchmarks for the region: simple cycle gas turbines and combined cycles.

GEMSET Model Features

The GEMSET evaluations cover (or will cover, when the project is complete) the entire United States, breaking the U.S into 12 different evaluation regions, as shown in the left column of the exhibit on the following page. There are dramatically different circumstances in each region: the regions differ in load growth, makeup of the existing fleet of generation, different choices of competitive or regulated power generating entities, etc. For each of these regions, assessment begins with a thorough characterization of the current fleet and the way planning and operations occur in the region. These characterizations establish the following:

GEMSET Evaluation Breakdown Regions

GEMSET Regional Characterizations



- CALPX – The California Power Exchange, a portion of the NERC's Western Systems Coordinating Council (WSCC)
- East Central – East Central Area Reliability Coordination Agreement (ECAR)
- Florida – Florida Reliability Coordinating Council (FRCC)
- Mid-America – Mid-America Interconnected Network (MAIN)
- Mid-Continent – the US portion of the Mid-Continent Area Power Pool (MAPP)
- Northeast – the US portion of NERC's Northeast Power Coordinating Council (NPCC), excluding New York
- NYISO – The New York ISO, a portion of NERC's Northeast Power Coordinating Council (NPCC)
- PJM – the Pennsylvania, New Jersey, Maryland Interconnect, which comprises the NERC's Mid Atlantic Area Council (MAAC)
- Southeast – Southeast Electric Reliability Council (SERC)
- Southwest – Southwest Power Pool (SPP)
- Texas – Electric Reliability Council of Texas (ERCOT)
- Western – the US portion of the NERC's Western Systems Coordinating Council (WSCC), excluding California

GEMSET Fuel Regions

- GEMSET Fuel Region 1 – New England
- GEMSET Fuel Region 2 – Mid-Atlantic
- GEMSET Fuel Region 3 – East North Central
- GEMSET Fuel Region 4 – West North Central
- GEMSET Fuel Region 5 – South Atlantic
- GEMSET Fuel Region 6 – East South Central
- GEMSET Fuel Region 7 – West South Central
- GEMSET Fuel Region 8 – Mountain
- GEMSET Fuel Region 9 – Pacific

Legend:
- *= Existing characterization complete*
- *= Planned characterization, or characterization underway when this paper was written*

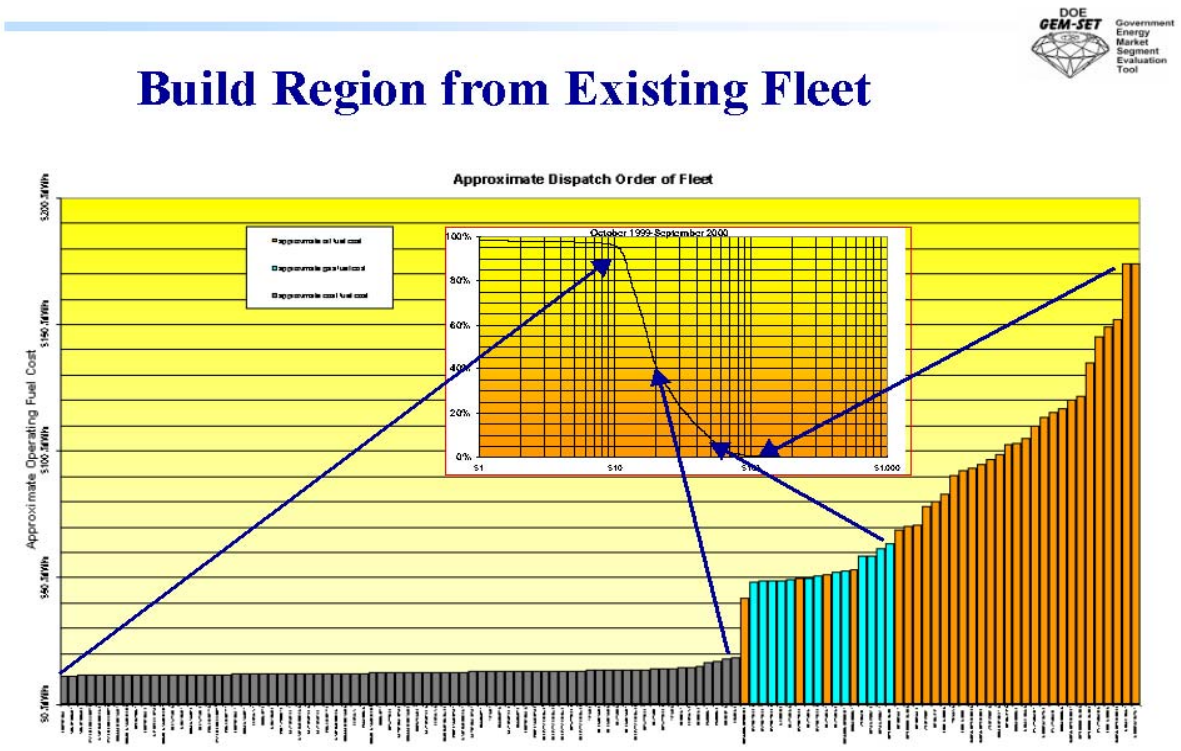
- Characterize the hour-by-hour load demand for each of the power companies, and summarized for the entire the region.
- Develop a database that characterizes an estimate of the regional cost of generation for each level of load demand that depends on assessments of the heat rate of each unit, presumptions of operating costs, and assessment of the expected fuel costs in the region.

- Assess fuel prices for the GEMSET fuel evaluation regions (right-hand column in the graphic above on the right-hand side), and project fuel price for future evaluations. In GEMSET, averages of the actual delivered price of the various fuels are used as the historical basis, commodity market closings for near-term history and forecasts, and EIA fuel price projections for long-term fuel cost trends.
- Establish the variable cost of operating and maintaining the unit so that it functions when actually dispatched by the Independent System Operator (ISO) or other load dispatch entity. Since each unit has its own particular set of operating costs, the GEMSET model uses reasonable industry averages for the differing types of units.
- Assess expectations of the production cost (in regulated regions), or the threshold bid price strategy (in competitive regions), for each unit.
- Identify the rack-up of the dispatch order expected for units operating in the region at each load level. If at a condition different from the historical record, re-estimate the new dispatch order under the study's demand profile unit makeup and fuel price scenario under investigation.
- Estimate the expected unit dispatch for each hour of the year, and develop capacity factor estimate profiles.
- If the region is competitive, develop an hour-by-hour assessment of competitive market price return expectation, if regulated, the rate base return expected. This allows ease of evaluation of the potential financial return to owners of units having different production costs.
- Evaluate fixed charge rate for each plant type based on certain financial parameters. The primary financial aspects related to each plant type are the capitalization ratio of debt versus equity, and the interest rate currently associated with electric generation projects by the financial community. The calculated fixed charge rate includes taxes, insurance, allowance for funds used during construction, the interest rate, and the capitalization ratio of debt and equity.
- Estimate expected future return based on reasonable projections of how the price structure might alter depending on the forecast future circumstances. In competitive regions, predict future bid strategies based on historical bids.
- Establish a reasonable future expectation of the region's demand growth, and the list of planned units that might meet that demand growth.
- Identify potential unit retirements in each region.
- Estimate production costs, threshold bid price, revenue, and levelized busbar cost of electricity (COE) that might occur under this scenario. The calculated COE for each of the technologies is a function of the cost components described above. These include the cost of fuel, calculated by taking the assumed capacity factor (number of hours operating) times the unit size and heat rate times a cost of fuel; the fixed and consumable cost of operation and maintenance; and the annual fixed charge rate to recover the cost of capital.

Stacking the Existing Fleet and Projecting the Stack in the Future

The GEMSET model system stacks the existing fleet of generation on the basis of the estimated threshold for bidding in a competitive market, or on production cost in a regulated market. Each unit within a geographical region is stacked with the lowest production cost units presumed

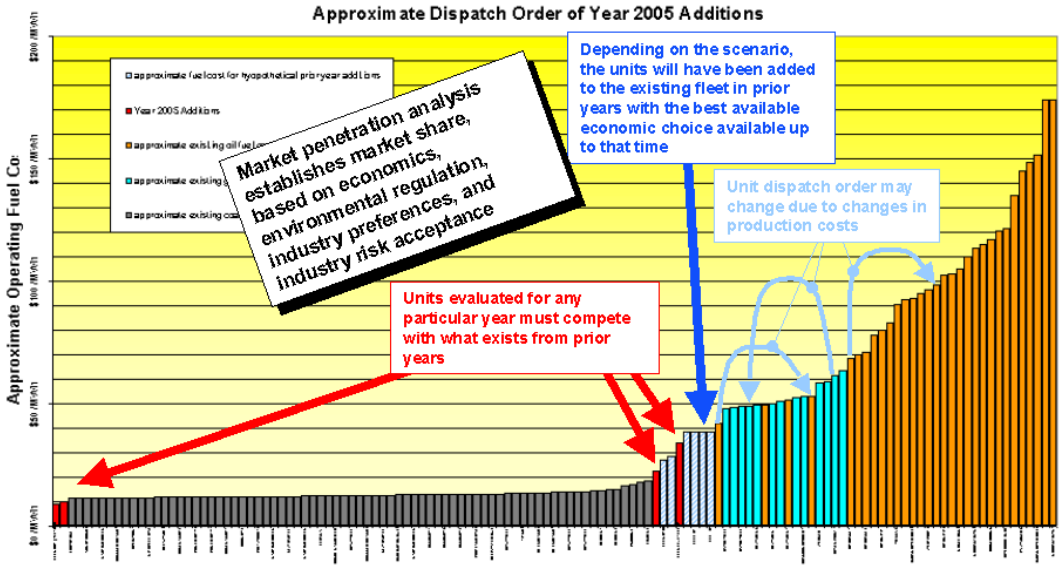
dispatched first, in higher and higher order, until all existing units in the region are sequenced. This process is illustrated in the graphic below.



Re-Stacking the Dispatch Order

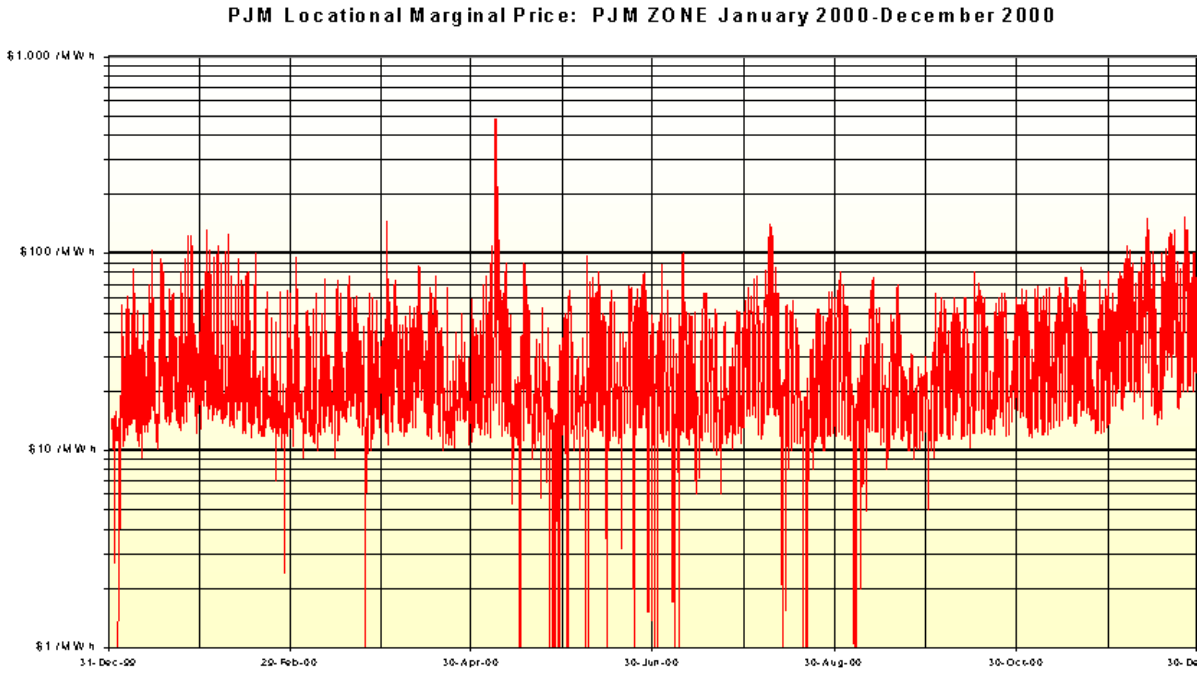
The first action needed to build the expectation of a different scenario's day-ahead electric price profile is to re-stack the units considered. These must be re-stacked in the revised threshold bid price order. The threshold bid prices of units will change since fuel price or demand profile, or other factors might change in any scenario, compared to the circumstance that existed in the historical data baseline. In any given scenario, individual units will likely have a different production order than in the baseline. For example, suppose natural gas price were presumed lower in an evaluation scenario. In this case, several natural gas units have been "promoted" in their dispatch order to earlier dispatch, while oil units were "demoted" since their scenario threshold bid price places the lower-priced units ahead of what have now become more costly units. The graphic below is a sketch to give a visual impression to illustrate the concept. The actual GEMSET re-stacking process is more sophisticated.

Re-stacking the Fleet to Establish Threshold Bid Prices vs. Demand Relationship for a Scenario



Mapping Price

Competitive prices are obtained for the prior year, and mapped hour by hour. Suitable assumptions are made for the mapping of each unit to this profile, for each hour's demand throughout the year. This is illustrated below for the PJM region beginning in the first hour of 2000 until the last hour of 2000.



Projecting Future Circumstance

Forecasts of capacity factor expectations, prices, and return are then made based on reasonable assumptions or assumed scenarios for the project:

- Demand growth hour-by-hour in future years.
- Fuel prices and other variable operating costs.
- Environmental regulation, and costs to comply with future regulation.

Fleet Additions and Retirements

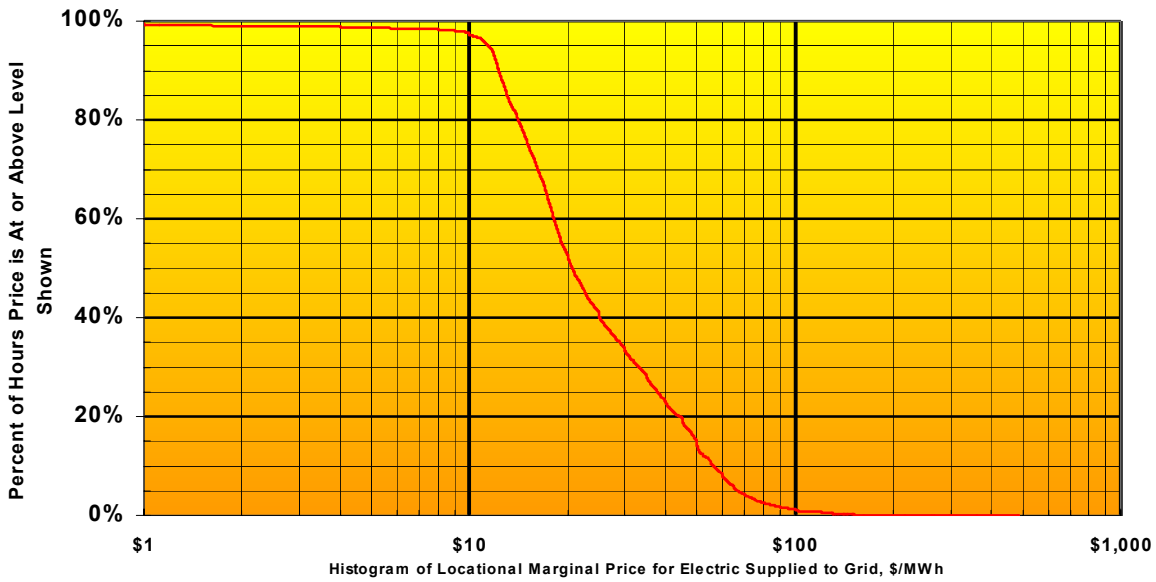
In the forecast, fleet additions are estimated for each year based on the presumed best economic choices for generating company owners. Decisions are made between new generation types, repowering options, and decisions on retirements. From the new fleet makeup, a new hour-by-hour forecast is made of the threshold prices expected of this new fleet, and the units re-stacked accordingly. Using the forecasts of hour-by-hour demand growth, fuel price, and environmental regulatory environment for a given evaluation scenario, the fleet costs are re-mapped to provide a price estimate.

Financial Benefit Evaluation

From the new price profile estimates, the potential return for new generation projects is estimated. The potential revenue stream, capacity factor, and operational profile for a candidate unit provide the information needed to assess the financial return prospects for a generation project. This analysis is done in the GEMSET system where the financial data are analyzed within set parameters regarding operational costs, capital costs, and expected return based on the revenues projected within the region selected.

Presumed Dispatch

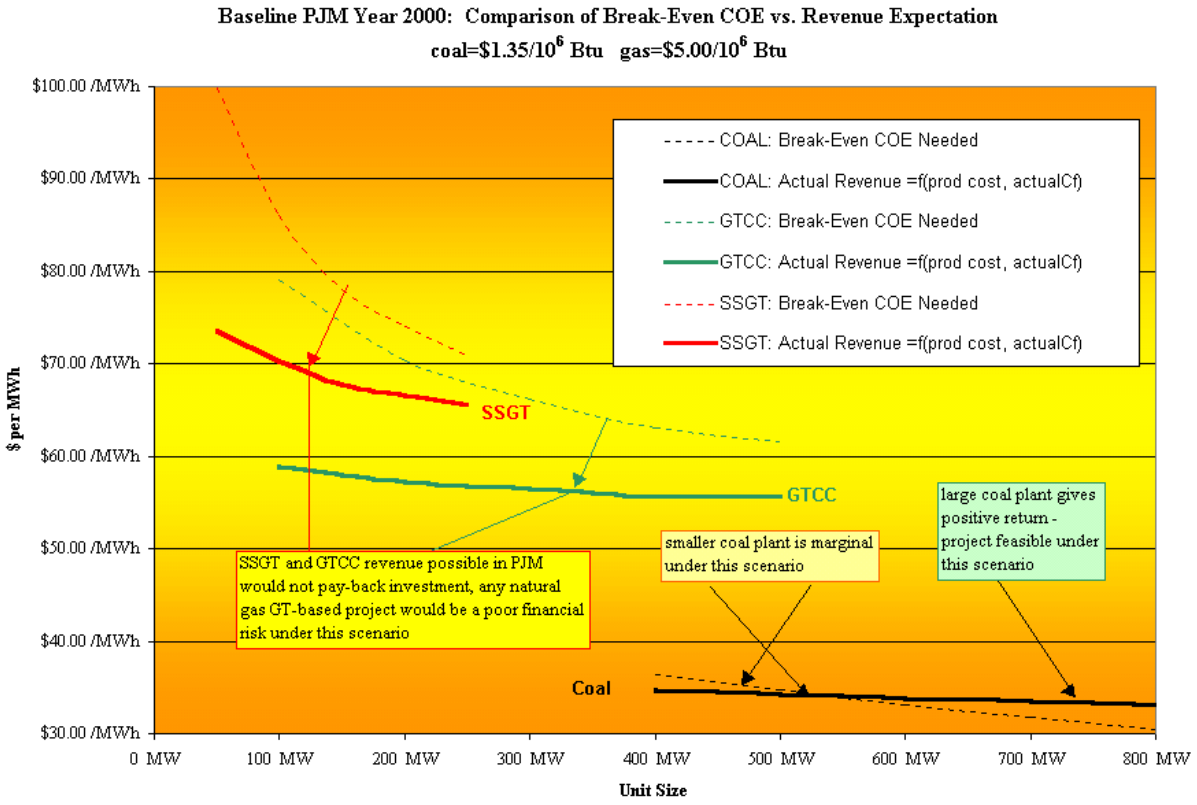
Having calculated a break-even COE needed to recover the capital investment for each of the differing units, it is necessary to compare that break-even COE to the current revenue they might receive in the region. Based on an hour-by-hour accumulation of day-ahead prices, a histogram is developed from the lowest to the highest price experienced in the region. This cumulative distribution function has a characteristic S-curve shape and is shown graphically below. This histogram is the basis for the assumed dispatching levels of the new units under current market conditions in the PJM region as an example.



By reading the price on the curve at the level of threshold bid prices for that unit, the number of hours that the unit is likely to be dispatched is calculated. This then gives the estimated dispatch levels and the capacity factor of the unit. With that S-curve is a corresponding calculation of the estimated revenue associated with that remaining number of hours of operation, which can then be compared against the calculated required COE to see if the unit can make a positive rate of return for the owner. In the graphics shown below are calculations of the revenue expected from the assumed capacity factor of the unit. That revenue amount is divided by the amount of production from that capacity factor and is compared against the required break-even COE for each unit at the differing sizes and heat rate efficiencies. If the revenue calculation is higher than the required COE, then the return to the owner is expected to be positive and profitable.

An example makes it easier to see how this is done. Below is a graphical summary of the economic performance of three types of generating technologies used as benchmarks for GEMSET studies, and their expected revenues when compared against the break-even revenue amount from PJM's pricing levels for the year 2000. Any owner considering buying a new generation unit would likely compare the technical and economic merits of his candidate against these three: a simple cycle natural-gas fueled gas turbine, a combined cycle fueled on natural gas, or a conventional sub-critical coal-fueled pulverized coal steam unit equipped with pollution control equipment.

SSGT, GTCC, and Pulverized Coal Project Break-Even COE versus Potential PJM Revenue with Year 2000 PJM Day-Ahead Electric Price



In this example case's investigation scenario, a summary of the three types of generation under investigation using average year 2000 fuel prices only, the coal unit achieved some level of return at the larger sizes. If, however, an owner had secured a long-term contract natural gas price at the gas price that existed in the beginning of 2000, then each unit size for the natural gas type units would actually make a positive rate of return.

Handling the Randomness of Competitive Market Effects in Order to Forecast Alternate Scenarios

While threshold bid price is an important driver for bid price, in a competitive market there are many reasons why bid price varies. It is assumed that these "gamesmanship" effects are a "random walk," and driven by competition and business strategy. In GEMSET, however, it is presumed that on average the competitive gamesmanship market variability of cost versus bid price that actually occurred in the prior year will likely be similar to that in any given scenario.

In GEMSET, an "inferred competition ratio" is established for each hour of the year, and presumed in the aggregate to reasonably approximate competitive variability in other years and scenarios. This ratio maps hour-by-hour the presumed threshold bid price for each hour's demand level and establishes the ratio between cost to the actual day-ahead price in that hour. That hour-by-hour baseline inferred competition ratio is then used to map all future scenarios. It is presumed that while any given hour is random, the aggregate trend of competitive pressures

will over a year range through similar variations. That is, while an individual hour cannot be predicted with any accuracy due to the random nature of competition, still, over 8,760 hours, the amount of variability between price and demand is more likely to be similar on average.

General Concerns

When evaluating any type of generating unit in a competitive market, it must be understood that production cost used in the traditional manner by system planners no longer applies in terms of least cost. It is now a situation whereby the owner must ask whether the plant can be run a sufficient number of hours at some threshold price to achieve a positive rate of return.

Most electric sales contracts, even in a competitive market, are bi-lateral arrangements whereby someone arranges in advance to purchase some or all of the output of that facility. The price at which that unit is paid for operation must cover all operating expenses and a return on the capital expenditure. Within GEMSET, the following rules apply:

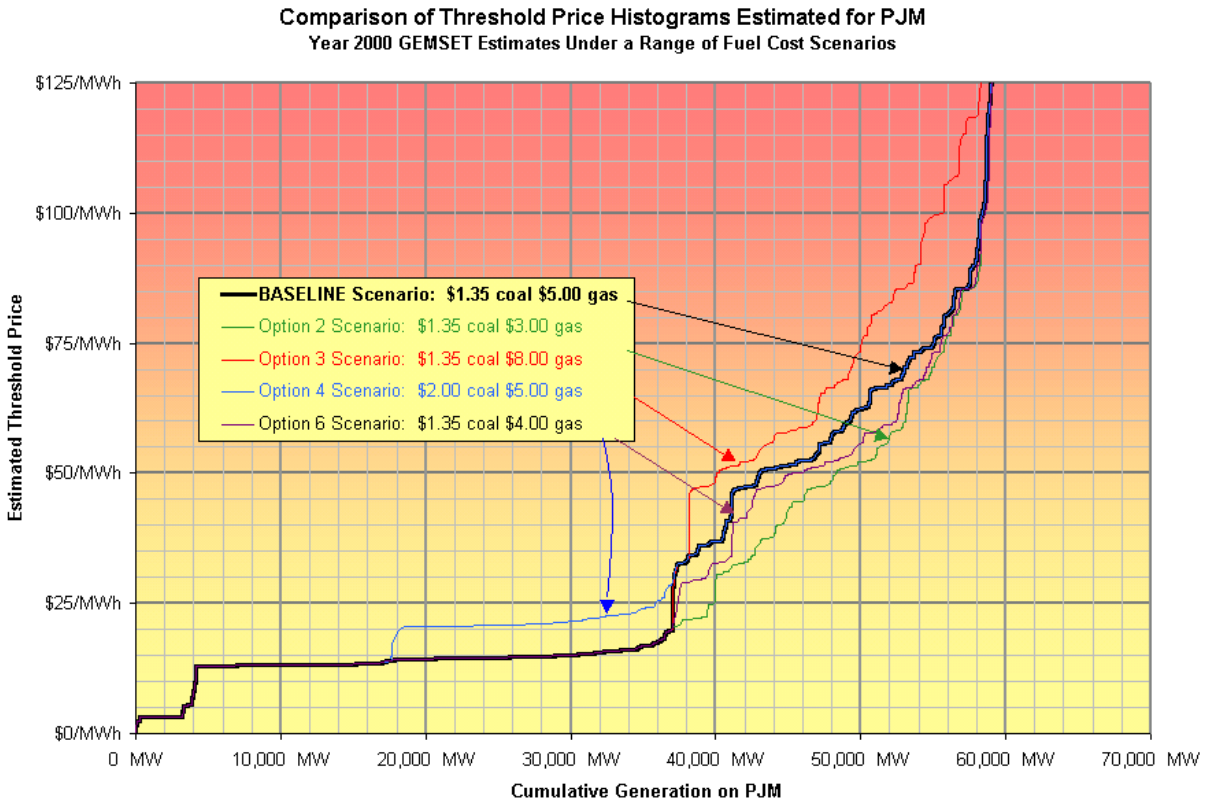
The Market Projections Assume:

- The region's bi-lateral contract price will trend toward the day-ahead free-market price.
- Market price is only loosely linked to threshold bid price; there is a large "random-walk" on any given hour; however, it is presumed that there is a tendency that price is linked to demand in some fashion.
- If a competitor has a lower marginal threshold bid price than another, he can always underbid that other competitor and win, whenever demand is less than the owner's particular marginal price dispatch order.
- On average, the market price will deviate about the price / demand / supply. While an individual hour cannot be accurately predicted, it is presumed here that on average, the deviations about a predicted level will have similar variability to those of the actual market in the prior year. That is, a scenario's variations about price versus threshold bid price will on average be similar to the variations that actually occurred in the prior year.
- The study presumes that differences in electric price under these several fuel price scenarios are not large enough to substantially alter demand in the region.

Example of Threshold Bid Price and Price Projections Under the Different Study Scenarios

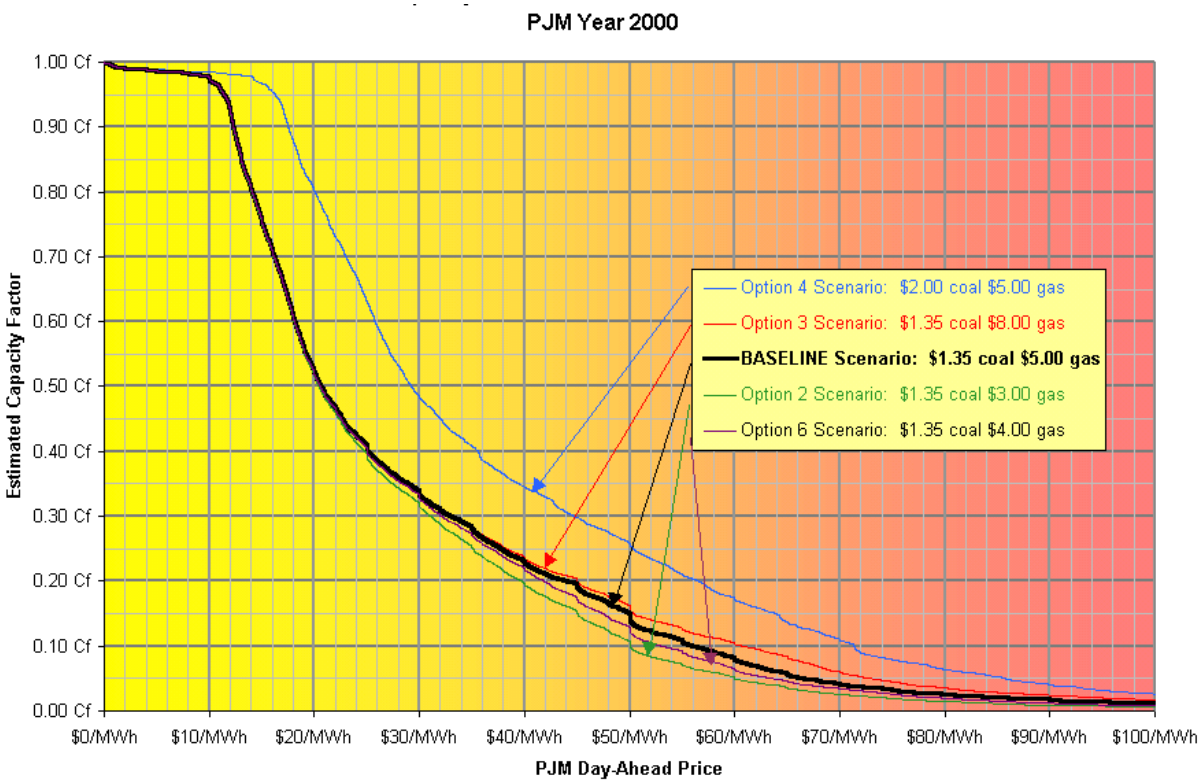
The estimated production units in PJM are evaluated under the several scenarios of fuel price. In each scenario, every unit in PJM is re-stacked according to its expected threshold bid price under that particular scenario. This results in the estimated threshold bid price histograms for each scenario shown below.

Threshold Bid Price Estimated for Each of the Study Fuel Cost Scenarios



The estimates of threshold bid prices under the several scenarios of fuel price in PJM were then mapped against hour-by-hour demand for each scenario. This presumed that differences in electric price in each case were not large enough to substantially alter demand in the region. Competitive electric bid price variability versus threshold bid price was assumed to be about the same under each scenario. From this, estimated day-ahead price was mapped. This results in the estimated day-ahead price histograms for each scenario shown next. These curves provide the capacity factor information used in the economic studies.

Estimated PJM Day-Ahead Price for Each of the Study Fuel Cost Scenarios



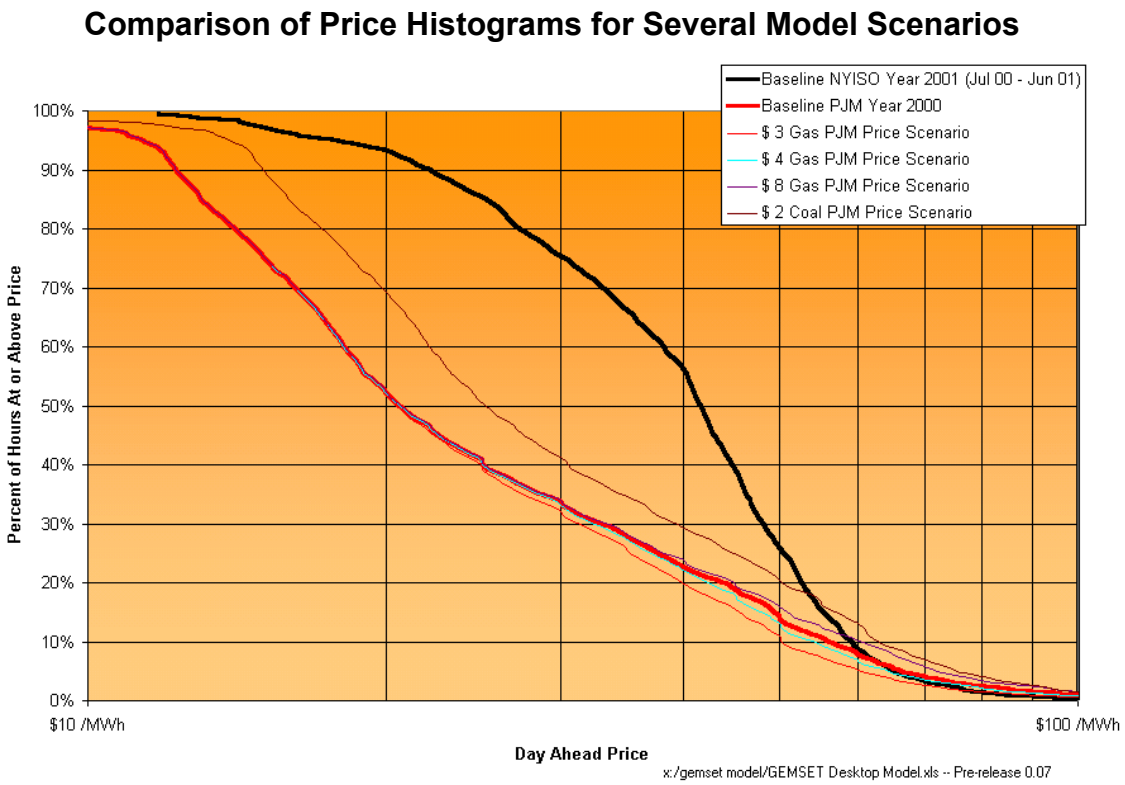
Stacking of Existing Units Within a Regional Scenario

The units in the PJM region were characterized using information from a number of databases. As an example, there are 497 units in the GEMSET unit database for the PJM region. The heat rates and the variable operating costs for each of these units was estimated as part of the analysis. Using the fuel costs discussed earlier, threshold bid price can be estimated. The threshold bid price is the point where a power plant owner decides to generate in a competitive region. If the revenue from the market is greater than this threshold, the owner would run the unit. If the revenue possible from the operation is lower, the owner would not offer power for sale until the price were higher. Generally, it is expected one would run the unit only when it earns revenue, and not run when it costs more in fuel and operating costs than the market price at the moment. There are times -and gamesmanship conditions- when it is worthwhile to operate at a loss for short periods, for example: in periods of temporary low price if it avoids a start-stop cycle.

Threshold bid price does not include a capital component, since those costs are captured in the capacity obligation prices. It is also important to understand that even though operating costs are met, it does not necessarily mean that adequate return is being received to service the debt.

Price Histograms

With the development of the various scenarios, a price histogram of each of the scenarios is developed, with a typical comparison similar in appearance to that shown below. As indicated in the chart, under varying fuel price assumptions, and when compared against the actual yearly data for both PJM and NYISO, the prices do change, but not dramatically.



Planned Work

This paper reports on a work in progress. Presuming the ability to secure continued funding of this effort, the GEMSET model building will continue until each remaining U.S. region is first characterized. Those regions under evaluation or soon to be evaluated include: ECAR, MAIN, MAPP, remainder of NPCC, SERC, SPP, ERCOT, remainder of WSCC. Evolving- and new-technology introductions will be placed on a consistent time-line. This will expand the present base of technologies to provide introduction-time consistency for future forecasts.

Environmental modeling of the fleet of units serving the regions is planned, so regional impacts of various environmental regulation scenarios can be investigated. The GEMSET team plans to provide regional environmental estimates, and economic assessments based on different possible future regulatory circumstances. This option, when later enabled, will provide for the region's future environmental baseline for estimating the fleet reaction to environmental compliance scenarios, and reflect the expected changes in electric price, capacity factor, and return of new units operating against a fleet confronted with meeting that environmental compliance challenge. The environmental scenario assessment is extremely important in the overall evaluation of the robustness of investment for coal-fired power facilities.

When these several modeling efforts are finished, the model will be complete, and the effort will then shift from model building to periodic maintenance of the currency of the various regional and technical data.

Since many U.S.-developed power technologies will likely have worldwide application, it is possible that some international regional characterization modeling will be considered in the future.

Conclusions

The U.S. is in a new mode of electric power sales, with new pressures on plant owners when evaluating the risks of spending millions of dollars on any new generating unit in the competitive market. There are no longer guaranteed rate of returns for today's owners. Because of this, the investment decision methods needed are changing. Modeling the expected future circumstances that might affect an owner's return has become sophisticated, and the forecasting planning it requires to assess the financial prospects has become significant. This paper describes one method that provides a reasoned approach for modeling the economic prospects for new electric generation plants as this new type power generation market emerges.

Acknowledgment

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